Solar-powered Livestock Watering Systems

Livestock Technical Note

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Abstract: This publication gives an introduction to solar-powered livestock watering systems, including discussions of cost, components, and terminology, as well as some suggestions for designing and installing these systems. The strengths and weaknesses of solar pumping are compared to the main options for pumping in remote locations: mechanical windmills and portable generators powered by gas, propane, or diesel fuel. The publication also includes descriptions of three successful projects and a brief resource list.

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October 2002

Introduction

Remote or off-grid power sources—including solar panels, mechanical windmills, and portable generators—can pump water for livestock in locations where electricity from power lines is unavailable. By encouraging animals to move away from lakes and streams, these systems give livestock greater access to forage. They also reduce livestock pressure on stream banks—preventing nutrient loading, damage to streamside vegetation, erosion, and pollution.

Solar pumping works anywhere the sun shines, and most parts of the United States have plenty of sunlight to run these systems. Solar pumping is a natural match for summer grazing applications, since it produces the greatest volumes of water in sunny weather and during long summer days—exactly when animals need water the most. With proper precautions, solar pumping systems can be used through the winter months too, even though shorter daylight hours will cause reduced water output.

Why should you consider installing a solar-powered livestock watering system on your farm or ranch? These factors may affect your decision:

- Distance from power lines and the cost of a line extension
- Operation and maintenance cost of a solar system compared to the alternatives, such as a mechanical windmill or a gasoline, propane, or diesel-powered generator
- The uncertainty of future electricity prices
- Rising costs of propane, gasoline, and diesel fuel
- Season of use—summer versus winter

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Cost

Many people considering a solar water pumping system are put off by the initial expense. Looking at the big picture, though, gives a better idea of the actual cost. For one thing, utility line extensions commonly cost $10,000 to $30,000 or more per mile. One rule of thumb is that remote pumping (whether solar-, wind-, or generator-powered) is worth considering whenever the distance from the utility grid exceeds about one-half mile. Where power lines are readily available they will generally provide the cheapest source of power.

Looking at the big picture also means factoring in installation, fuel, and maintenance costs over the life of the project. When you include all these factors you may find that solar is an economical choice.

How do you choose between solar power, a mechanical windmill, and a gas-, propane-, or diesel-powered generator? No two pumping situations are alike, but here are a few guidelines:

Solar-powered systems have a relatively high initial cost compared to the other remote pumping options. Solar-powered systems are also often described as having comparatively low operation and maintenance costs. This may very well be true. Keep in mind, though, that many solar components are of fairly recent design, so reliability data tend to be lacking. In 2002, the typical cost for a small to moderate-sized solar pumping system suitable for stock-watering is $2,500 to $7,500, not including installation cost or well-drilling. Despite the steep initial cost, there are site-specific situations where solar-powered systems can be chosen based on economic reasons alone. The cost advantages of solar pumping are generally strongest in low-head and low-volume situations.

Solar pumping replaced a gas-powered generator on the Tomlinson Ranch near Gold Creek, MT.

Prices increase sharply where large volumes and deep wells are involved. NCAT estimated costs for six demonstration solar pumping projects over an assumed 10-year period. The cost of water per cow ranged from $0.03 to $0.15 per day. The cost per gallon of pumped water ranged from $0.002 to $0.007 per gallon.

Gas- or propane-powered generators often have a lower initial cost than mechanical windmills or solar power. But many low-end gas-powered generators require frequent maintenance and have a design life of only about 1500 hours, making them a costly and labor-intensive option in the long run. On the other hand, better-quality generators have many strong points. A high-quality self-starting propane-powered generator operates unattended, runs day and night, is easy to install, should last for many years, and is especially well-suited for situations involving deep wells and high volumes of water.

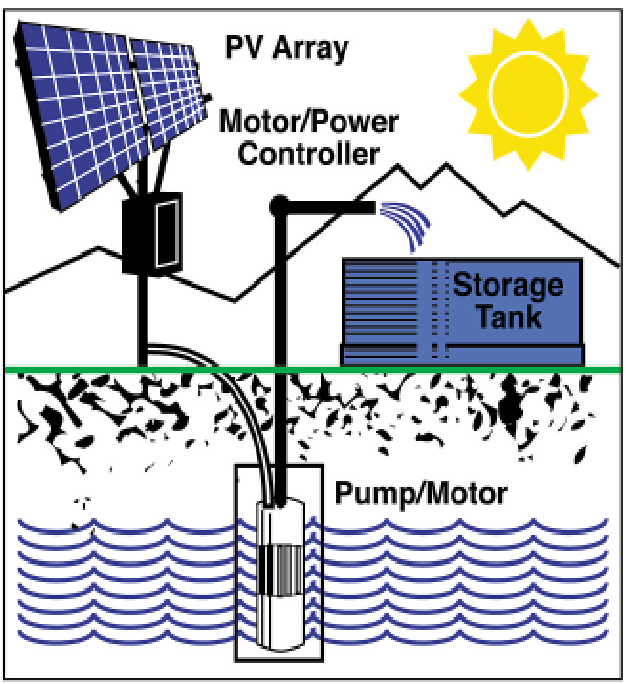
Although they cost about one-third more than comparable gas-powered generators, *diesel-powered generators* will usually have a lower initial cost than wind- or solar-powered systems. In low-head and low-water-volume situations a solar-powered system will generally produce cheaper water than a diesel-powered generator. On the other hand, where large volumes of water are required a diesel-powered system may produce cheaper water than a solar-powered system.

Mechanical windmills usually have a somewhat higher initial cost than comparable solar or generator-based pumping systems. Installation often requires specialized equipment, and some studies have shown higher typical maintenance costs for windmills compared to solar-powered systems. Since no fuel is required, the operating costs for a windmill are typically lower than those for a generator-based system. Windmills generally last longer than most solar pumps. In a good location—where average wind speed is above about seven miles per hour—a wind-powered pump may produce cheaper water than a solar-powered pump.

All of the points just made should be taken with a grain of salt. The technologies for and costs of solar-, wind-, and generator-powered pumping are continually changing. (For example, no effort is made here to evaluate wind-electric or wind / solar hybrid pumping systems.) Every option has its advantages, and it bears repeating that every pumping and stock-watering situation is site-specific.

Solar Pumping Technology—What You Need to Know

Before talking to a dealer, you should become acquainted with the terms and equipment:



A typical solar-powered stock watering system includes a solar array, pump, storage tank and controller.

Solar Modules

Solar electric systems are sometimes called *photovoltaic* systems. The word "photovoltaic" is often abbreviated "PV." Solar panels, or *modules*, generate direct current (DC) electricity. A group of modules is called an *array*. Modern solar panels are designed to withstand golf-ball-sized hail and usually come with 20-year (or longer) warranties.

Mounting Structures

There are two ways to mount solar modules: either on a fixed structure or on a tracking structure. Fixed mounts are less expensive and tolerate higher winds but have to be oriented to face true south (not magnetic south). The tilt angle also needs to be adjusted. The usual recommendation is to adjust the tilt angle to latitude minus 15 degrees for summer use or latitude plus 15 degrees for winter use, and set the tilt equal to latitude for year-round operation. For example, if you were located at 40 degrees latitude you would set the tilt angle at 25 degrees in the summer and 55 degrees in the winter, or else leave the tilt angle at 40 degrees year-round.

A tracking array follows the sun across the sky. A tracker will add at least $400 to $800 to the cost of a system, but in many cases this is a good investment since trackers can increase water volume by 25 percent or more in the summertime, compared to a fixed array. Trackers are generally "passive," meaning that they use no electricity. A liquid stored in the tracker is warmed by sunlight and flows through tubing to the opposite side of the tracker. The weight of the fluid causes the tracker to tilt the panels toward the sun.

Once the panels are fastened to a mounting structure, the system can easily be put on a trailer to make it portable. Towing the trailer from one pasture to another makes it possible to follow animals through a rotation and pump water from the nearest well, stream, or pond.

Pumps

In general, DC water pumps use one-third to one-half the energy of conventional AC (alternating current) pumps. DC pumps are classed as either *displacement* or *centrifugal*, and can be either *submersible* or *surface* types.

Displacement pumps use diaphragms, vanes, or pistons to seal water in a chamber and force it through a discharge outlet—similar to the way your heart pumps blood. *Centrifugal* pumps use a spinning impeller that adds energy to the water and pushes it into the discharge outlet, similar to the way water sprays off a spinning bicycle tire. *Submersible* pumps, placed down a well or sump, are highly reliable because they are not exposed to freezing temperatures, do not need special protection from the elements, and do not require priming. *Surface* pumps, located at or near the water surface, are used primarily for moving water through a pipeline. Some surface pumps can develop high heads and are suitable for moving water long distances or to high elevations.

Storage

Batteries are usually not recommended for solar-powered livestock watering systems because they reduce the overall efficiency of the system and add to the maintenance and cost. Instead of storing electricity in batteries, it's generally simpler and more economical to install 3 to 10 days' worth of water storage tanks. Adding batteries to a system may make sense, however, if a continuous flow of water is needed during nighttime and cloudy weather.

Controller or Inverter

The *pump controller* protects the pump from harmful high or low voltage and maximizes the amount of water pumped in less-than-ideal light conditions. An AC pump requires an *inverter*—an electronic component that converts DC electricity from the solar panels into AC electricity to operate the pump.

Other Equipment

A *float switch* turns the pump on and off when filling the stock tank. It's similar to the float in a toilet tank but is wired to the pump controller. *Low-water cut-off electrodes* protect the pump from low-water conditions in the well.

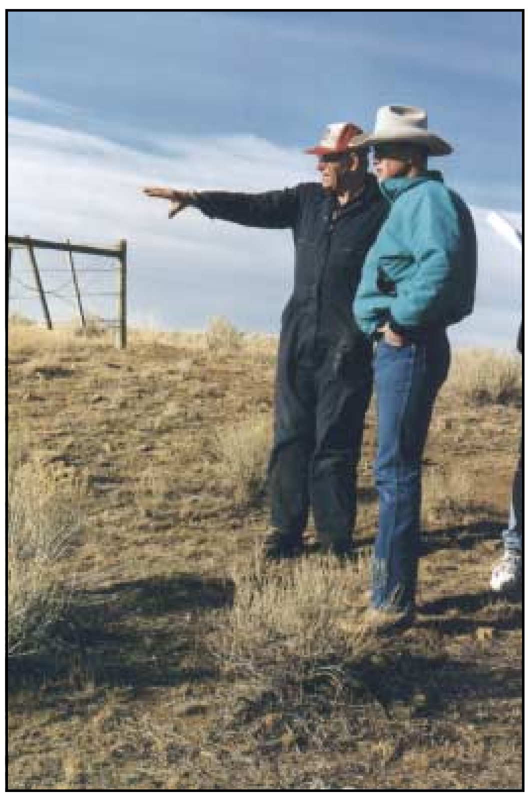
Designing and Installing Systems

The average consumer is likely to be intimidated by the prospect of sizing and designing a solar pumping system, and most people need help from a qualified solar dealer. In general, dealers are eager to help. Many will provide a no-cost proposal based on a few simple questions you can answer over the phone. If the price seems too high, you can easily get bids from other dealers.

In order to size and design a system correctly, the dealer will want to know:

- How much water you need
- When you need the water
- Whether your water source is a stream, pond, spring, or well
- Water available in gallons per minute (gpm)
- Well depth
- How far the water needs to be pumped, and with what elevation gain
- Water quality problems (e.g., silt or high mineral content) that may damage the pump
- How much volume is available in storage tanks and how the tanks are arranged

Based on these factors, the dealer will recommend a system, putting together a list of suitable components. This is one area where the dealer's experience and familiarity with systems is essential. A dealer can also save you



time and aggravation by providing the correct hardware: clips, screws, nuts, bolts, washers, cable (cut to correct lengths), and assorted wiring and connectors. The customer usually provides peripheral items, such as water piping and fittings, tanks, the mounting-structure support post, concrete, and grounding materials.

Installing a solar pumping system is generally something the landowner can do. A few words of caution are necessary, however. Installing one of these systems is a complex task, combining elements of electrical work, plumbing, and heavy construction (often including earthmoving, concrete-pouring, and welding). Written instructions are not always as complete as they should be. A backhoe or tractor with a front-end loader is almost a necessity for some larger projects.

Project Descriptions

Ballard Ranch

Lavina, Montana

When their old water-pumping windmill finally died, Jim and Adele Ballard installed a solar pumping system to replace it. The new system pumps water from a 65-foot-deep well to a pair of stock tanks holding about 4000 gallons. Four 80-Watt PV modules on a tracking rack power a submersible piston pump that delivers a maximum flow rate of 5.5 gpm, enough to water 100 cow / calf pairs. The system produces average flows of 2000 to 3000 gallons per day (gpd) during the summer months. Solar component costs: $5,500.

A tracking PV array replaced an old and unreliable windmill on the Ballard Ranch near Lavina, MT.

This solar pumping system on the Hirsch Ranch near Deer Lodge is protecting stream banks along Racetrack Creek, an important trout spawning stream.

Hirsch Ranch

Racetrack, Montana

Rick and Pam Hirsch installed a solar pumping system on a 10-foot-deep backhoe-dug well on their property to water 36 cow / calf pairs. The pumping system uses two 64-Watt PV modules, a passive tracking rack, and a submersible diaphragm pump equipped with a sand shroud and low-water cut-off electrodes to protect the pump. The system is designed to produce flows of 2600 to 2800 gpd during the summer months. Solar component costs: $2,400.

Painted Robe Watershed Group, Lavina, Montana

The Painted Robe Watershed Group has been developing off-stream sources of drinking water for cattle along Painted Robe Creek, a tributary to the Musselshell River with water quality problems. The group received a trailer-mounted solar pumping system from the Montana Department of Environmental Quality. It was first installed on the Leo Schraudner Ranch to water 150 cattle at the site of a 60-foot-deep well. Seven 60-Watt panels on a fixed trailer-mounted rack use an inverter to convert solar-produced DC to the AC electricity needed by the submersible centrifugal pump. Water is pumped into two 1100-gallon tanks. The system is designed to produce average flows of 2880 to 4000 gpd during the summer months. Solar component costs: $10,650.

A trailer-mounted PV system is improving range management and water quality along Painted Robe Creek near Lavina, MT.

Resources

Water Pumping: the Solar Alternative

This 67-page guide, first published in 1987 by Sandia National Laboratories, includes chapters on design considerations, system selection, cost, and economics of solar pumping systems. You can order a copy from:

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161
(800)553-6847
Or download an Adobe Acrobat .pdf version of this document from http://www.sandia.gov/pv/lib.htm

Electricity When and Where You Need It: From the Sun - Photovoltaics for Farms and Ranches

This 28-page guide, published in 1997 by the National Renewable Energy Laboratory, includes chapters on pumping water, power for buildings, applications around the ranch, and working with the sun.

You can download an Adobe Acrobat .pdf version of this report (#MK-411-21732) from: http://www.nrel.gov/publications/

Solar-Powered Livestock Watering Systems, by Michael J. Buschermole and Robert T. Burns.

This 16-page guide, published by the Agricultural Extension Service at the University of Tennessee, includes system configurations as well as guidelines for selecting, installing, and maintaining solar pumping systems. You can order a copy from:

Agricultural Extension Service
University of Tennessee
301 Agricultural Engineering Building
2506 Chapman Drive
Knoxville, TN 37996-4531
(865) 974-7266
Or download an Adobe Acrobat pdf version of this document from http://www.utextension.utk.edu/pbfiles/pb1640.pdf

The Montana AgSolar Project

This 86-page report, published by The National Center for Appropriate Technology in December 2000, includes case studies, research on the market potential for solar pumping in Montana, and an overview of current technology.

A downloadable Adobe Acrobat pdf version of this report is available from http://www.montanagreenpower.org

Solar equipment dealers and manufacturers are also a good source of information. View their websites or check the yellow pages for dealers in your area.

Edited by Richard Earles
Formatted by Gail Hardy

October 2002

The electronic version of **Solar-powered Livestock Watering Systems** is located at:
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